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(54) **LIQUID PROCESSING APPARATUS**

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G05D 7/06 (2006.01)
H01L 21/67 (2006.01)

(52) **U.S. Cl.**
CPC ***G05D 7/0664*** (2013.01); *H01L 21/67017* (2013.01); *Y10T 137/85986* (2015.04)

(58) **Field of Classification Search**
CPC H01L 21/67017; G05D 7/0664; Y10T 137/85986
USPC 137/565.11, 565.27, 486, 111, 599.05
See application file for complete search history.

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(57) **ABSTRACT**

A liquid processing apparatus includes a first line to which a processing liquid pressurized by a pump is sent from a processing liquid supply source; a plurality of second lines into which the pressurized processing liquid flowing through the first line flows; a branch line connected to a branch point on each of the second lines; a liquid processing unit configured to process a substrate with the processing liquid; an orifice provided at an upstream side of the branch point; and a first control valve provided at a downstream side of the branch point. The first control valve changes an amount of the processing liquid flowing to a downstream side of the first control valve to control a pressure of the processing liquid in a section between the orifice of the second line and the first control valve, and to control a flow rate of the processing liquid.

4 Claims, 3 Drawing Sheets

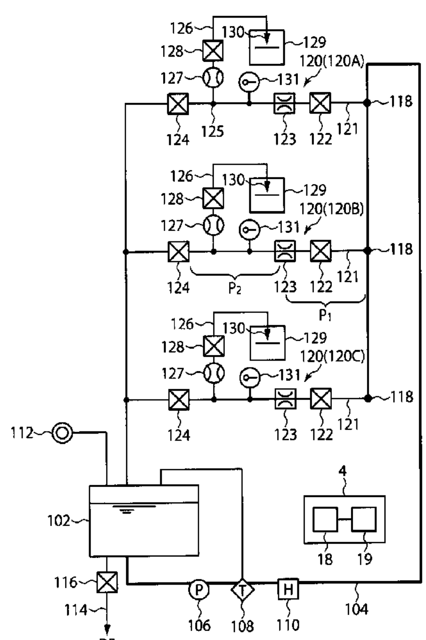
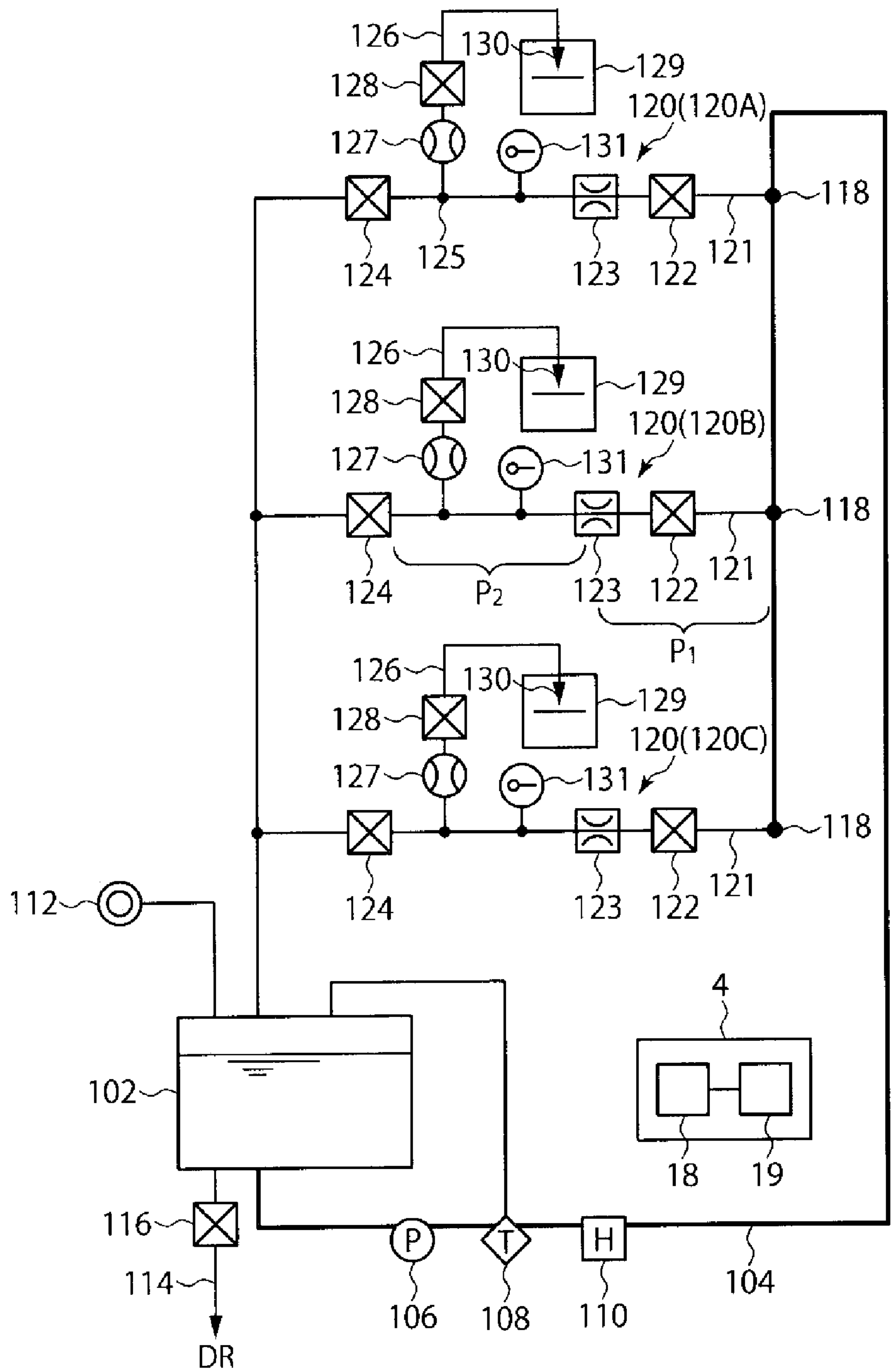


FIG. 1


126
130
129
128
120(120A)
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127
131
118
124
P2
123
122
121
P1
126
130
129
128
120(120C)
127
131
118
124
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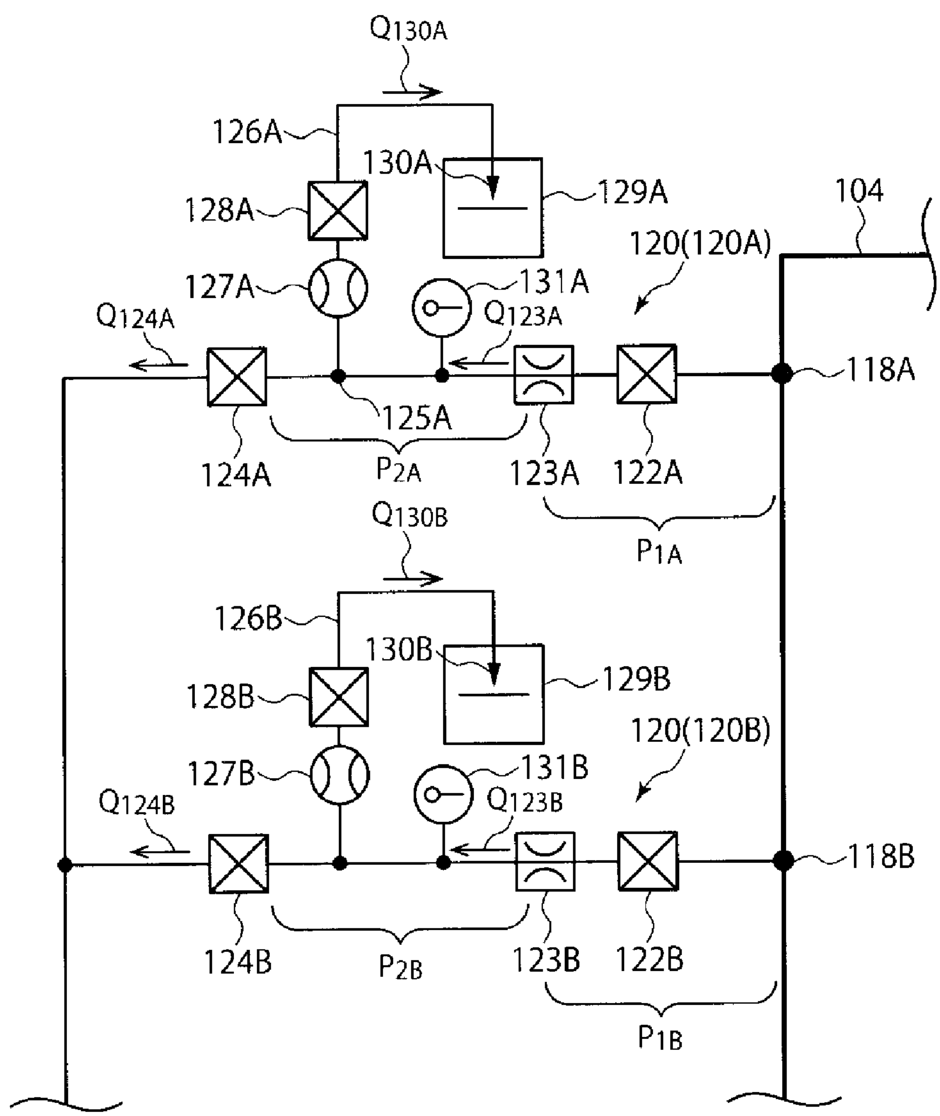
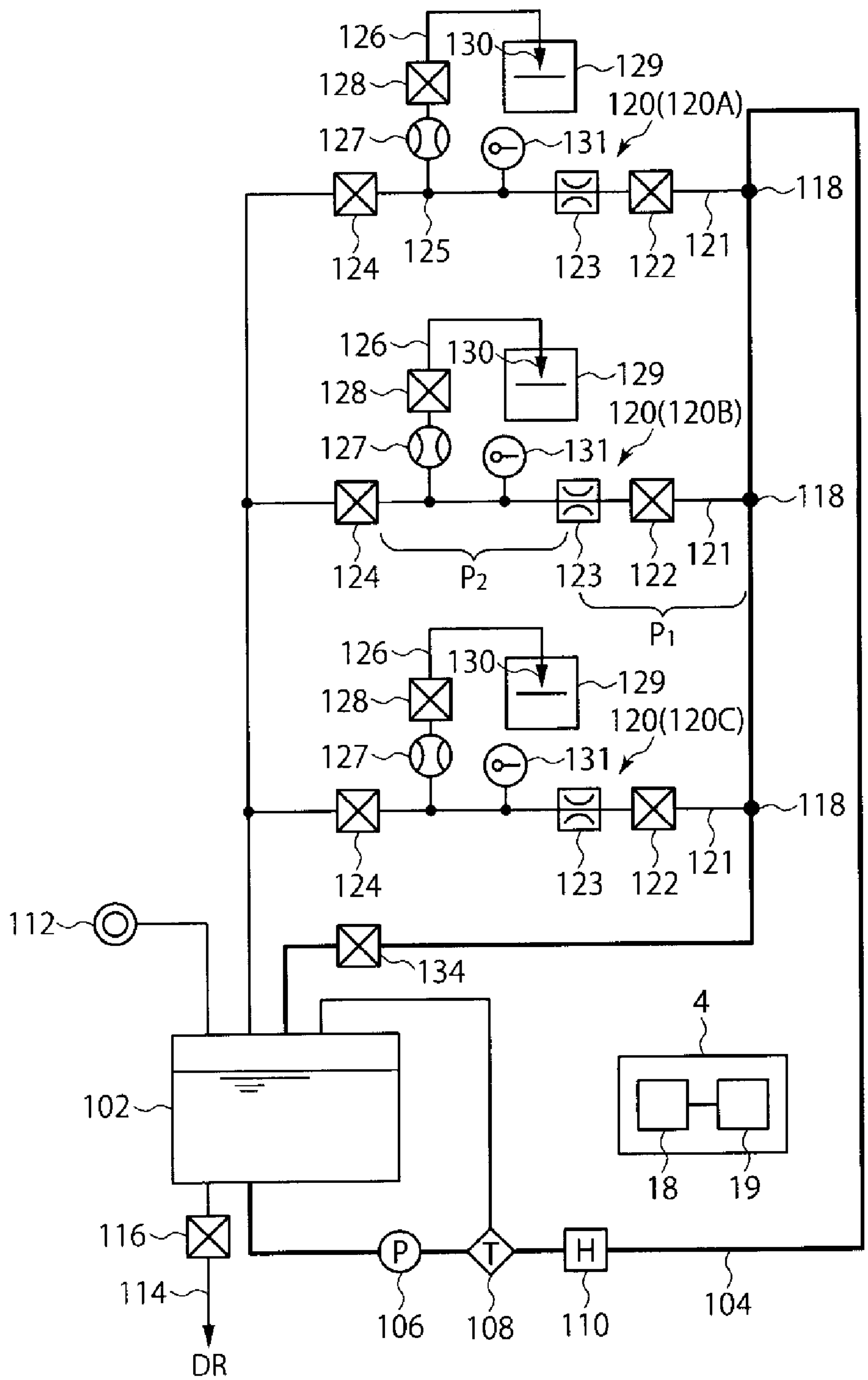
FIG. 2



Q130A
126A
130A
129A
104
128A
120(120A)
127A
131A
Q124A
Q123A
118A
125A
124A
P2A
123A
122A
Q130B
P1A
126B
130B
129B
128B
120(120B)
127B
131B
Q124B
Q123B
118B
124B
P2B
123B
122B
P1B

FIG. 3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P2
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122
121
P1
126
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128
120(120C)
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LIQUID PROCESSING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on and claims priority from Japanese Patent Application No. 2013-173759, filed on Aug. 23, 2013 with the Japan Patent Office, the disclosure of which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

The present disclosure relates to a technique for controlling a flow rate of a processing liquid supplied to a liquid processing unit in a liquid processing apparatus in which a predetermined liquid processing is performed on a substrate.

BACKGROUND

In manufacturing semiconductor devices, a liquid processing such as, for example, a cleaning processing or a wet etching processing is performed on a substrate such as a semiconductor wafer. In order to perform such a liquid processing, a liquid processing system provided with a plurality of liquid processing modules (liquid processing units) is used. The liquid processing system is provided with a processing liquid storing tank, a circulation line that goes out of the processing liquid storing tank and goes back to the processing liquid storing tank, and a pump configured to form a flow of a pressurized processing liquid in the circulation line. A plurality of branch lines branches in parallel from the circulation line, and the processing liquid is supplied to each of the liquid processing modules from the branch lines. A flowmeter and a flow control valve are interposed in each of the branch lines. Based on a detection value of the flowmeter, a feedback control of the flow control valve is performed such that a flow rate of the processing liquid supplied to a substrate by the liquid processing module becomes a desired value (see, for example, Japanese Patent No. 3841945).

When a valve body of the flow control valve is moved frequently in the feedback control, particles may be generated inside the flow control valve. The generated particles are supplied to a substrate along with the processing liquid passing through the branch lines. Here, when the particles are generated at a problematic level, it is necessary to provide a filter to remove the particles. However, provision of a filter causes a problem in that a regular maintenance of the filter is required.

SUMMARY

In a suitable exemplary embodiment, the present disclosure provides a liquid processing apparatus including: a first line connected to a processing liquid supply source; a pump configured to send a processing liquid from the processing liquid supply source to the first line; a plurality of second lines connected to the first line; a branch line connected to a branch point on each of the plurality of second lines; a liquid processing unit configured to perform a liquid processing on a substrate with the processing liquid supplied through each branch line; an orifice provided at an upstream side of the branch point on each of the plurality of second lines; and a first control valve provided at a downstream side of the branch point on each of the plurality of second lines. The first control valve changes an amount of the processing liquid flowing to a downstream side of the first control valve to control a pressure of the processing liquid in a section between the orifice of a corresponding second line and the first control valve, and to control a flow rate of the processing liquid supplied to the corresponding liquid processing unit through the corresponding branch line.

The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view illustrating a processing liquid circuit of a liquid processing apparatus according to a first exemplary embodiment.

FIG. **2** is a view for explaining an operation of the first exemplary embodiment.

FIG. **3** is a view illustrating a processing liquid circuit of a liquid processing apparatus according to a second exemplary embodiment.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawing, which form a part hereof. The illustrative embodiments described in the detailed description, drawing, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here.

The present disclosure provides a liquid processing apparatus in which particles that may be generated from a control valve for flow control of a processing liquid supplied to a liquid processing unit is not supplied to the liquid processing unit.

In a suitable exemplary embodiment, the present disclosure provides a liquid processing apparatus including: a first line connected to a processing liquid supply source; a pump configured to send a processing liquid from the processing liquid supply source to the first line; a plurality of second lines connected to the first line; a branch line connected to a branch point on each of the plurality of second lines; a liquid processing unit configured to perform a liquid processing on a substrate with the processing liquid supplied through each branch line; an orifice provided at an upstream side of the branch point on each of the plurality of second lines; and a first control valve provided at a downstream side of the branch point on each of the plurality of second lines. The first control valve changes an amount of the processing liquid flowing to a downstream side of the first control valve to control a pressure of the processing liquid in a section between the orifice of a corresponding second line and the first control valve, and to control a flow rate of the processing liquid supplied to the corresponding liquid processing unit through the corresponding branch line.

The above-described liquid processing apparatus may further include a flowmeter provided on each of the branch lines; and a control unit configured to control the corresponding first control valve based on a flow rate detected by the flowmeter to control the flow rate of the processing liquid flowing through the corresponding branch line.

In the above-described liquid processing apparatus, the processing liquid supply source is a tank configured to store the processing liquid, and a portion at the downstream side of the branch point of each of the second line is communicated with the tank.

In the above-described liquid processing apparatus, the processing liquid supply source is a tank configured to store the processing liquid, and the first line is formed as a circulation line which goes out of the tank and goes back to the tank.

In the above-described liquid processing apparatus, a second control valve is provided in the first line at a downstream side of a connection point to the first line of the second line which is connected to the first line at the most downstream side of the first line such that the second control valve changes an amount of the processing liquid flowing to a downstream side of the second control valve to control a pressure in the first line at an upstream side of the second control valve.

According to the present disclosure, since it is not necessary to interpose a control valve for flow control in the branch line, particles that may be generated from such a control valve do not flow in the liquid processing unit.

Hereinafter, exemplary embodiments of the present disclosure will be described with reference to the accompanying drawings. A first exemplary embodiment will be first described.

A liquid processing apparatus is provided with a tank **102** serving as a processing liquid supply source. The processing liquid tank **102** is connected with a main line (first line) **104**. The main line **104** is provided with a pump **106**, a filter **108**, and a heater **110** in this order from an upstream side thereof. The pump **106** sends a processing liquid, which is stored in the tank **102**, in a pressurized state towards a downstream side of the main line **104**. The filter **108** removes contaminants such as particles from the processing liquid. The heater **110** heats the processing liquid to a predetermined temperature. When the processing liquid is used at a normal temperature, the heater **110** may not be provided. The tank **102** is replenished with a processing liquid or a processing liquid component from a replenishment device **112**, as necessary. The processing liquid in the tank **102** may be drained through a drain line **114** provided with an opening/closing valve **116**. For convenience of explanation, the "main line (first line)" is used to refer to a portion indicated by a bold line.

At a plurality of connection points **118** set on the main line **104**, the main line **104** is connected with a plurality of subsidiary lines (second lines) **121**. Downstream ends of the plurality of subsidiary lines **121** are connected to the tank **102**.

In the exemplary embodiment illustrated in FIG. **1**, the downstream ends of the plurality of subsidiary lines **121** are joined with each other and then connected to the tank **102**. However, the downstream ends of the plurality of subsidiary lines **121** may be connected to the tank **102** separately.

One subsidiary line **121** is provided with an opening/closing valve **122**, an orifice **123**, and a first control valve **124** (to be described later in detail) sequentially from an upstream side thereof. At a branch point **125** set in a downstream side of the orifice **123** of the subsidiary line **121** and in an upstream side of the first control valve **124**, the subsidiary line **121** is connected with a branch line **126**. The branch line **126** is provided with a flowmeter **127** and an opening/closing valve **128** sequentially from an upstream side thereof. Downstream ends of the branch line **126** is connected with a processing liquid nozzle **130** provided in a liquid processing unit **129** (also referred to as a 'liquid processing module'). The subsidiary line **121** is provided with a thermometer **131** between the orifice **123** and the branch point **125**.

The liquid processing unit **129** is configured to perform a predetermined processing on a substrate such as a semiconductor wafer by supplying the processing liquid from the processing liquid nozzle **130** to the substrate. The liquid processing unit **129** includes, for example, a spin chuck (not illustrated) configured to hold and rotate the substrate, and a receiving cup (not illustrated) surrounding the periphery of the substrate to receive the processing liquid scattered from the substrate.

Components provided in connection with each subsidiary line **121** (the members represented by reference numerals **121** to **130**) are the same as each other. A set of the components **121** to **130** associated with each subsidiary line **121** is represented by a reference numeral **120**.

The first control valve **124** may be a valve of any type having a function to change an amount of the processing liquid flowing to an outlet (downstream side) of the first control valve **124** such that a pressure at an inlet (upstream side) thereof is maintained at a predetermined target pressure. The first control valve **124** may be, for example, a back pressure valve.

The liquid processing apparatus is provided with a control device **4**. The control device **4** is, for example, a computer, and includes a control unit **18** and a storage unit **19**. The storage unit **19** stores a program that controls various processings performed in the liquid processing apparatus. The control unit **18** controls the operations of the liquid processing apparatus by reading and executing the program stored in the storage unit **19**.

Further, the program may be recorded in a computer-readable recording medium, and installed from the recording medium to the storage unit **19** of the control device **4**. The computer-readable recording medium may be, for example, a hard disc (HD), a flexible disc (FD), a compact disc (CD), a magnet optical disc (MO), or a memory card.

Next, actions will be described with reference to FIG. **2**. In the following, in order to distinguish the same elements belonging to different sets, symbols 'A', 'B', and 'C' will be accompanied to the ends of the reference numerals as necessary. FIG. **2** illustrates only a part related to component sets **120**A, **120**B, which is extracted from the processing liquid circuit illustrated in FIG. **1**. Here, it is assumed that the same liquid processing is performed on a substrate in each of liquid processing units **129**A, **129**B. The opening/closing valve **122** is always opened during normal operation of the liquid processing apparatus, and is closed only in a special case such as maintenance.

Here, a pressure P_{1A} at an upstream side of an orifice **123**A of a subsidiary line **121**A is set to 140 kPa. Further, a pressure P_{1B} at an upstream side of an orifice **123**B of a subsidiary line **121**B is set to 150 kPa. Such a difference between the pressure P_{1A} and the pressure P_{1B} is generated, for example, due to a difference in water head near connection points **118**A, **118**B, which is caused by a difference between heights where the liquid processing units **129**A, **129**B are provided.

Target flow rates Q_{130A}, Q_{130B} of the processing liquids ejected from processing nozzles **130**A, **130**B of the liquid processing units **129**A, **129**B are set to be the same and constant, respectively. Here, for example, the target flow rates Q_{130A}, Q_{130B} are set to be $Q_{130A}=Q_{130B}=2.5$ L/min In the example as illustrated, variable flow adjusting units are not provided on branch lines **126**A, **12**B of the respective sets **120**A, **120**B. Accordingly, the flow rates of the processing liquids ejected from the processing nozzles **130**A, **130**B monotonically increase (decrease) in accordance with an increase (decrease) in pressures P_{2A}, P_{2B} of regions between orifices **123**A, **123**B and first control valves **124**A, **124**B in the subsidiary lines **121**A, **121**B, respectively.

The pressure P_{2A} and the pressure P_{2B} required to realize $Q_{130A}=Q_{130B}=2.5$ L/min, that is, target pressures are the same as each other. Here, the target pressures are set to 100 kPa. In this case, a pressure drop of 140−100=40 kPa may occur in the orifice **123**A. In addition, a pressure drop of 150−100=50 kPa may occur in the orifice **123**B. Differences in pressure between inlets and outlets of the orifices **123**A, **123**B, P_{1A}-P_{2A}, P_{1B}-P_{2B}, monotonically increase (decrease) in accordance with an increase (decrease) in flow rates Q_{123A}, Q_{123B} of the processing liquids passing through the orifices **123**A, **123**B. As differences between the actual pressures P_{2A}, P_{2B} and the target pressure (100 kPa) increase, the flow rates Q_{124A}, Q_{124B} of the processing liquid passing through the first control valves **124**A, **124**B configured as back pressure valves increase. And, since the flow rates Q_{124A}, Q_{124B} increase, flow rates Q_{123A}, Q_{123B} also increase. Accordingly, the pressure P_{2A} and the pressure P_{2B} automatically converge to the target pressure. Various values described in FIG. **2** are those obtained after the pressure P_{2A} and the pressure P_{2B} automatically converge to 100 kPa which is the target pressure. For example, the flow rate Q_{124A} is equal to 0.5 L/min, the flow rate Q_{124B} is equal to 1.0 L/min, the flow rate Q_{123A} is equal to 3.0 L/min, and the flow rate Q_{123B} is equal to 3.5 L/min.

As described above, cooperative actions of the orifices **123**A, **123**B and the first control valve **124** formed as a back pressure valve allow the pressure P_{2A} and the pressure P_{2B} to be maintained at the target pressure, and the flow rates of the processing liquids supplied from the processing nozzles **130**A, **130**B to be controlled to be the target flow rate.

The processing liquids passing through the first control valves **124**A, **124**B are returned to the tank **102**, and sent again from the tank **102** to the main line **104**.

When it is not necessary to supply the processing liquid to the liquid processing unit **129**, particularly, for example, when the liquid processing unit **129** does not perform a liquid processing (e.g., when performing a processing using a processing liquid supplied from another processing liquid circuit, when drying the substrate, or when exchanging the substrate), the opening/closing valve **128** of one of the component sets **120**A to **120**C to which the liquid processing unit **129** belongs, may be closed. Then, the processing liquid does not flow through the processing nozzle **130**. Instead, an amount of the processing liquid flowing through the first control valve **124** increases substantially by that amount. For example, in the example illustrated in FIG. **2**, when the opening/closing valve **128**A of the component set **120**A is closed, the processing liquid does not flow through the processing nozzle **130**A. Instead, an amount of the processing liquid flowing through the first control valve **124**A increases substantially by that amount. Thus, the amount of the processing liquid becomes about 3.0 L/min. Further, in this case, the pressure between the orifice **123**A and the first control valve **124**A is also maintained at the above-mentioned target pressure (100 kPa) by the first control valve **124**A formed as a back pressure valve.

As is clear from the above, the amount of the processing liquid flowing into the subsidiary line **121** from the main line **104** becomes substantially the same, regardless of whether or not the processing liquid is supplied to the liquid processing unit **129** belonging to any one of the component sets **120**A to **120**A. Therefore, since it is not necessary to change the amount of the processing liquid to be sent to the main line **104** by the pump **102** depending on the operation state of the processing unit **129** of each of the component sets **120**A to **120**C, the pump **102** may be stably operated. Further, although descriptions for the actions related to the component set **120**C are omitted, it is of course that the component set **120**C acts in the same manner as the component sets **120**A, **120**B.

In the exemplary embodiment described above, the first control valve **124** is a back pressure valve, but, instead of that, the first control valve **124** may serve as a variable throttle valve. In this case, the degree of opening of the variable throttle valve **124** may be feedback-controlled through, for example, the control device **4** by providing a pressure gauge (not illustrated) configured to measure a pressure P_2 in a section between the variable throttle valve **124** and the orifice **123** in the subsidiary line **121**, such that the detected pressure of the pressure gauge reaches a target value (for example, 100 kPa as described above).

Alternatively, based on a detected flow rate of the flowmeter **127**, the flow rate of the processing liquid supplied from the processing liquid nozzle **130** may be controlled to be the target flow rate by adjusting the degree of opening of the variable throttle valve **124** such that the detected flow rate reaches a target value (for example, 2.5 L/min as described above) through, for example, the control device **4**. In principle, the performance in this case is exactly the same as in the exemplary embodiment as described above. That is, when the pressure P_2 is higher (lower) than the target pressure, the detected flow rate of the flowmeter **127** becomes higher (lower) than the target flow rate. Therefore, in this case, when the degree of opening of the variable throttle valve **124** increases (decreases), the flow rate of the processing liquid passing through the variable throttle valve increases (decreases), and hence, the flow rate of the processing liquid passing through the orifice **123**A increases (decreases). As a result, the pressure P_2 converges to the target pressure.

However, in this case, when the liquid processing unit **129** belonging to a component set to which the variable throttle valve **124** belongs does not perform a liquid processing on a substrate, it may be desirable to maintain the amount of the processing liquid flowing through the subsidiary line **121** belonging to the component set at a substantially constant target flow rate. In such a case, for example, it is necessary to take the following measures. As a first measure, a flowmeter is provided on the subsidiary line **121**, and the degree of opening of the variable throttle valve **124** is feedback-controlled through, for example, the control device **4** such that a detected value of the flowmeter reaches the target flow rate. As a second measure, (although some variation may occur in the flow rate) when the liquid processing unit **129** belonging to a component set to which the variable throttle valve **124** belongs does not perform a liquid processing on a substrate, a command that causes the variable throttle valve **124** to be in a predetermined degree of opening is assigned to the variable throttle valve **124** from the control device **4**.

Further, as described above, in a case where a variable throttle valve (which may be a back pressure valve capable of varying a primary target pressure by an electric control) is employed as the first control valve **124**, when a heated processing liquid is used, a temperature adjustment of a subsidiary line **121** may be performed by adjusting a flow rate of the processing liquid flowing through a subsidiary line **121** when the processing liquid is not supplied to a liquid processing unit **129** belonging to any one of the component sets **120**A to **120**C to which the subsidiary line **121** belongs. In this case, when a temperature measured by the thermometer **131** is lower (higher) than a predetermined value, the flow rate of the processing liquid flowing through the subsidiary line **121** increases (decreases) by adjusting the degree of opening of the variable throttle valve **124** through, for example, the control device **4**.

In another exemplary embodiment, as illustrated in FIG. **3**, the main line **104** may be formed as a circulation line departing from the tank **102** and returning to the tank **102**. In this case, a second control valve **134** may be provided at a downstream side of the connection point **118** to the main line **104** of the subsidiary line **121** which is connected to the main line **104** at the most downstream side of the main line **104**. The second control valve **134** has a function to adjust a pressure in the main line **104** at an upstream side of the second control valve **134** by changing an amount of the processing liquid flowing to a downstream side of the second control valve **13**. The second control valve **134** may be, for example, a back pressure valve, and maintains, for example, the pressure in the main line **104** at an inlet of the back pressure valve at 150 kPa. The second control valve **134** may be a variable throttle valve. According to the configuration as illustrated in FIG. **3**, the second control valve **134** may further stabilize the pressure in the main line **104**.

The exemplary embodiments of the present disclosure have been described, but the present disclosure is not limited to the exemplary embodiments. For example, the substrate may be any substrate such as, for example, a glass substrate or a ceramic substrate, other than the semiconductor wafer. The number of component sets is not limited to three (3) as illustrated, and may be any number of one or more.

From the foregoing, it will be appreciated that various embodiments of the present disclosure have been described herein for purposes of illustration, and that various modifications may be made without departing from the scope and spirit of the present disclosure. Accordingly, the various embodiments disclosed herein are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

What is claimed is:

1. A liquid processing apparatus comprising:

a first line connected to a processing liquid supply source;

a pump configured to send a processing liquid from the processing liquid supply source to the first line;

a plurality of second lines connected to the first line;

a branch line connected to a branch point on each of the plurality of second lines;

a liquid processing unit configured to perform a liquid processing on a substrate with the processing liquid supplied through each branch line;

an orifice provided at an upstream side of the branch point on each of the plurality of second lines;

a first control valve provided at a downstream side of the branch point on each of the plurality of second lines;

a flowmeter provided on each of the branch lines; and

a control unit configured to control a corresponding first control valve based on a flow rate detected by the flowmeter to control the flow rate of the processing liquid flowing through a corresponding branch line,

wherein the first control valve changes an amount of the processing liquid flowing to a downstream side of the first control valve in order to control a pressure of the processing liquid in a section between the orifice of a corresponding second line and the first control valve, and a flow rate of the processing liquid supplied to the corresponding liquid processing unit through the corresponding branch line.

2. The liquid processing apparatus of claim **1**, wherein the processing liquid supply source is a tank configured to store the processing liquid, and a portion at the downstream side of the branch point of each of the plurality of second lines is communicated with the tank.

3. The liquid processing apparatus of claim **1**, wherein the processing liquid supply source is a tank configured to store the processing liquid, and the first line is formed as a circulation line which goes out of the tank and goes back to the tank.

4. The liquid processing apparatus of claim **3**, wherein a second control valve is provided in the first line at a downstream side of a connection point to the first line of each of the second lines which is connected to the first line at the most downstream side of the first line such that the second control valve changes an amount of the processing liquid flowing to a downstream side of the second control valve to control a pressure in the first line at an upstream side of the second control valve.

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